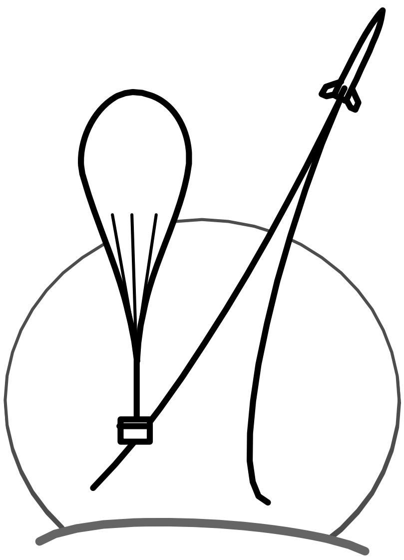

Motors for space clubs

Rocket motor data

Version 1.5 - March 2009

TABLE OF CONTENT

ACKNOWLEDGMENTS

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ED.	REV.	DATE	OBSERVATIONS
5	0	Feb 2002	Old version
1	1	17 Jan 2008	Pro54
1	2	21 Jan 2008	Pro-X schematics
1	3	12 Fev 2008	English translation
1	4	01 June 2008	Micro/mini/Pro75 motor
1	5	29 March 2009	Corrections

REGULATION

Manufacturing and handling powders and explosives are dangerous activities which are subject to strict regulation in France (pyrotechnics safety).

Since 1962, CNES (the French Space Agency) is proposing dedicated support and facilities for young amateurs which guarantee safety and allow enjoying leisure, education and experimentation through this activity.

This document gathers the entire main technical information useful to space clubs and motivated youth involved in a rocket project conducted within the program organized by CNES and Planète Sciences.

Motors described in this document are dedicated to this activity, and can only be set up by authorized pyrotechnicians from CNES or Planète Sciences.

CONDITIONS FOR MOTOR GRANT

From the moment a club decides to make use of a motor provided by CNES, it commits, in an implicit way, to conduct its project within the program defined by CNES and Planète Sciences.

A project will start with the exchange of documents and reviews (physical meetings) between the club and Planète Sciences (which is conducting the review of the space projects by delegation from CNES).

The exchanges will be materialized by:

- **Objectives definition**, containing the purpose of the project;
- **Definition review**, a discussion about the feasibility of the project, and about the choice of a motor in coherence with the objectives of the project.
- A **design review**, a discussion that seals the complete study of the project;
- A **progress review** or **pre-qualification review**, a meeting which can be seen as a rehearsal of the controls performed during the launch campaign;
- A **report of experiments**, describing the difficulties encountered, the positive aspects of the project and the results of the experiments conducted;

These reviews are also important in the club's life since they are the milestones of the project. They provide the opportunity to collect and archive documents related to the project in order to establish a library, on access to anyone and listing the projects of the clubs.

ⓘ **THE MOTOR WILL ALWAYS BE SELECTED BASED ON THE OBJECTIVES OF THE PROJECT. IN SOME CASE, CNES MAY PROPOSE ANNOTHER MOTOR THAN THE ONE ASKED BY THE CLUB.**

ⓘ **IN THIS PROCEDURE, THE CLUB COMMITS TO BUILD ITS ROCKET IN COMPLIANCE WITH THE DESIGN CONSTRAINTS, A DOCUMENT DISTRIBUTED BY PLANÈTE SCIENCES THAT LISTS A NUMBER OF BASIC RULES. THEY GUARANTEE THE SAFETY AND THE COMPATIBILITY WITH THE LAUNCHING FACILITUES PROVIDED BY PLANÈTE SCIENCES, WITH THE SUPPORT FROM CNES, AND MADE AVAILABLE TO THE CLUBS.**

SET UP

Set up of the motors for space clubs rocket affiliated with Planète Sciences and the CNES is performed by people trained for that (pyrotechnicians). Club members never handle the motor.

Motor Catégory	Set Up by	Launch location
MicroRocket	MicroRocket certified people	Multiples
MiniRocket	MiniRocket pyrotechnicians	Regional Campaigns
Experimental Rocket	Experimental Rocket pyrotechnicians	Yearly national Campaign

Each year in France, regional launch campaigns are organized by regional subsidiaries of Planète Sciences, who offered several dates and places. The national launch campaign is organized by CNES and Planète Sciences, and usually takes place at the time of summer holidays.

Controls and tests of motor compatibility with the rocket are performed with empty motor (still used or only motor case). These tests must be successful to obtain the launch authorization.

The motors are brought and prepared just before flight, near the launch pad. It’s the pyrotechnicians people who equip the rockets with the motor.

ⓘ **THIS IS THE REASON WHY THE DESIGN OF THE ROCKET MUST INTEGRATE THE POSSIBILITY TO LOAD AND UNLOAD THE ENGINE QUICKLY, IN THE OPEN AIR, BY A PYROTECHNICIAN WEARING PROTECTION GLOVES.**

Once the two parts (motor and rocket) are assembled, the pyrotechnician is able to install the igniter (electrical triggering) inside the motor. All of these actions take place in a wide-open area, away from the public. In these conditions, even if an incident would happen, it would only involve a limited number of people.

Passed this step, the pyrotechnician is giving the order to evacuate the launching area. Everything must take place quietly, and with silence……5…4…3…2…1…0, near the pyrotechnician, a club member is pressing the button on the trigger box…

ⓘ **FOR FURTHER DETAILS ABOUT THE SET UP OF PROJECTS, YOU CAN REFER TO THE TECHNICAL NOTE: « ASSISTANCE FOR THE WRITE-UP OF AN EXPERIMENTAL ROCKET CHRONOLOGY ». THE FRENCH VERSION IS AVAILABLE UNDER SIMPLE REQUEST TO PLANÈTE SCIENCES OR CAN BE DOWNLOADED HERE: WWW.PLANETE-SCIENCES.ORG/ESPACE/BASEDOC/**

MICROMOTORS

Presentation

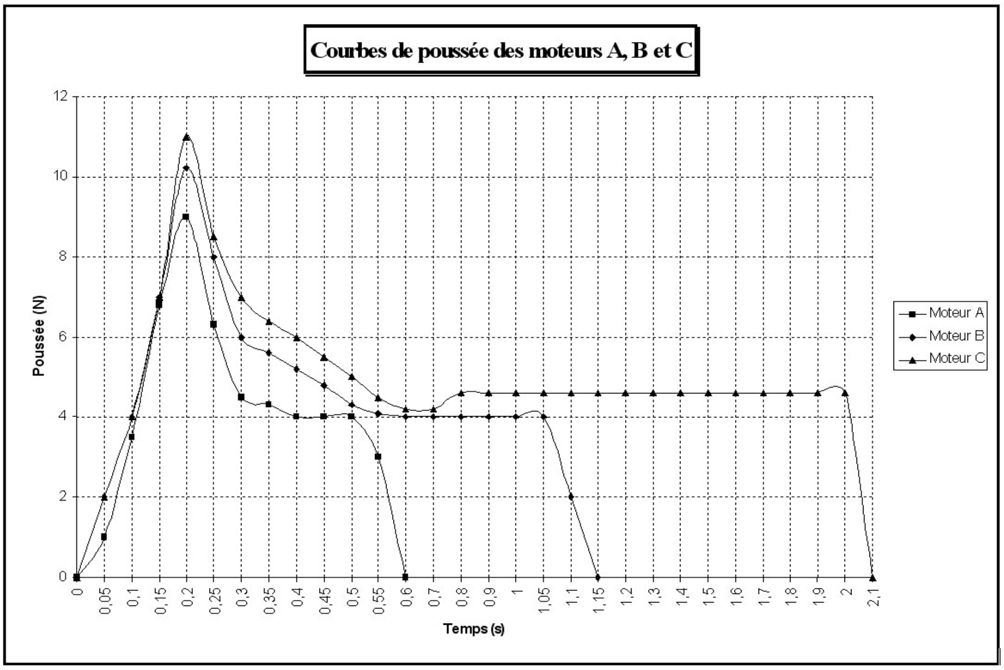
Micromotors correspond to the A, B, C category of motors. They are set up for the micro rocket activity such as proposed by Planète Sciences.

Specifications

The table below details the main specifications for micromotors retailed by Planète Sciences. Other types of micromotors exist, especially for the duration of the timer powder duration, given in seconds, by the 2nd digit of the code. They are not used or retailed by Planete Sciences.

	A 8-3	B 4-0	B 4-4	C 6-3	Unit
Total impulse	2.5	5	5	10	N.s
Thrust duration	0.32	1.2	1.2	1.7	s
Average thrust	14	13	13	13.5	N
Total mass	15	18	19	22	g
Net mass	10.8	12	13	9.5	g
Ejection time	3	0	4	3	s

Thrust Curve



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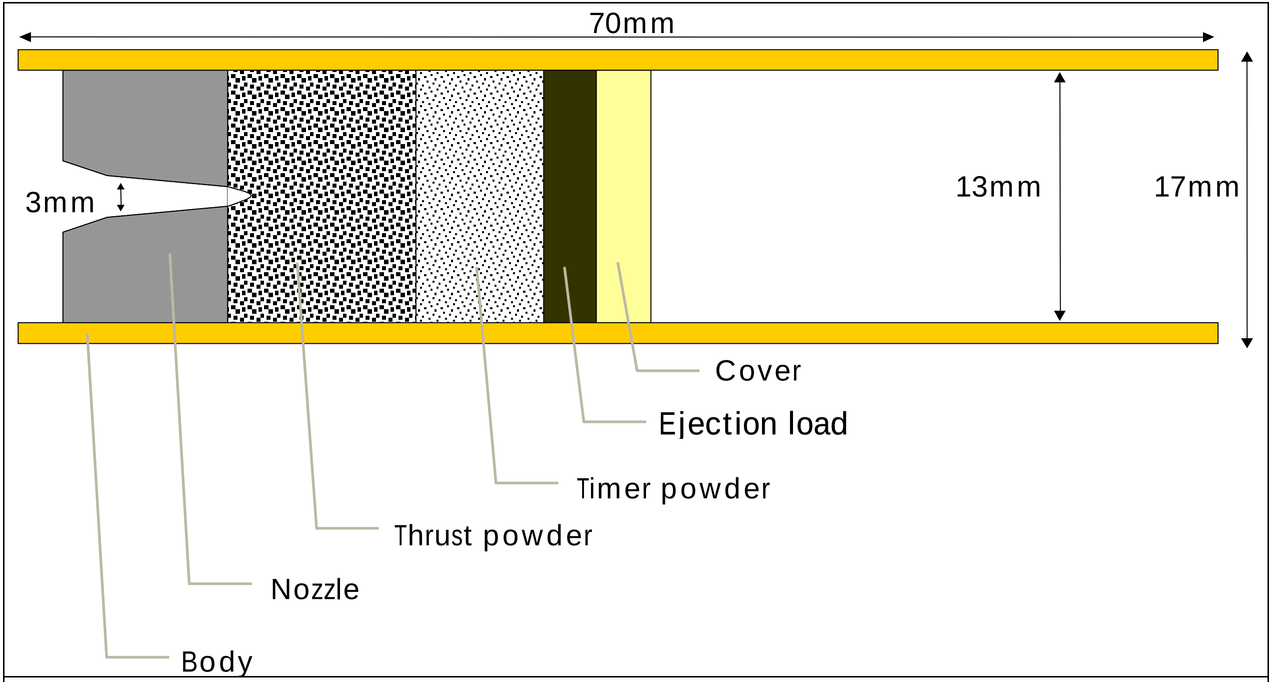


Overview of a micromotor

Rocket interfaces

Micromotors can be in inserted inside 20mm inner diameter cardboard tubes, widely used in Microrocket activities. Space between motor and tube is filled by a few layers of tape or paper wrapped around the motor.

WAPITI

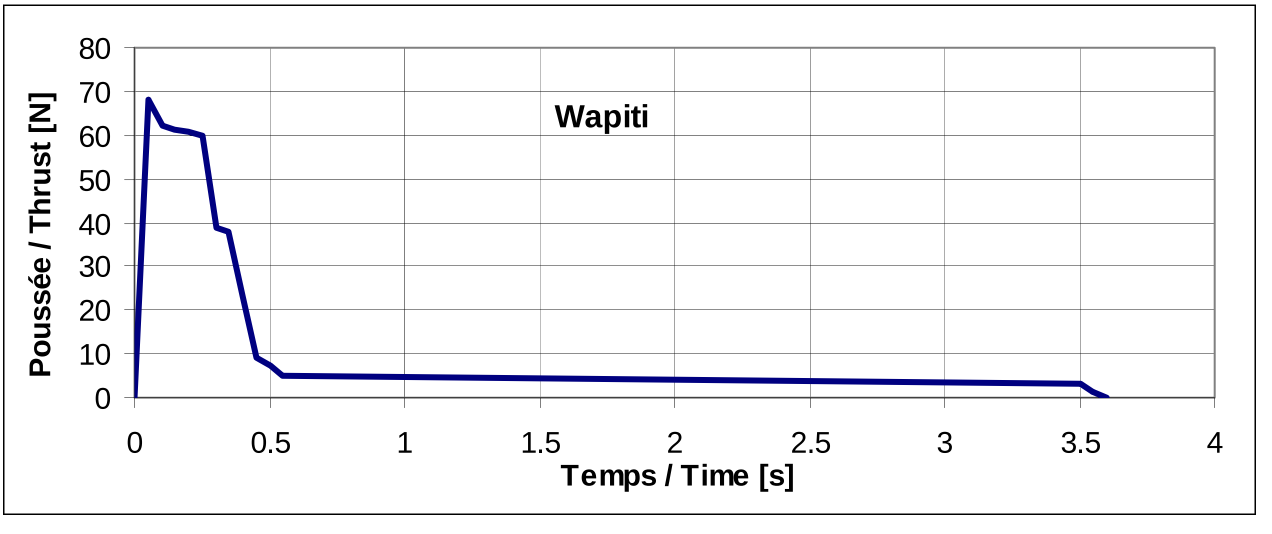
Presentation

WAPITI is a motor for mini rocket used since 1998; it is a type E motor based on rocket motors classification.

Specifications

	WAPITI	Unit
Total impulse	33 to 40	N.s
Thrust duration	3.2 to 3.6	s
Maximum thrust	68 to 80	N
Average thrust	10.7	N
Total mass	85	g
Net mass	35	g
Centre of gravity [2]	20	mm

Thrust Curve



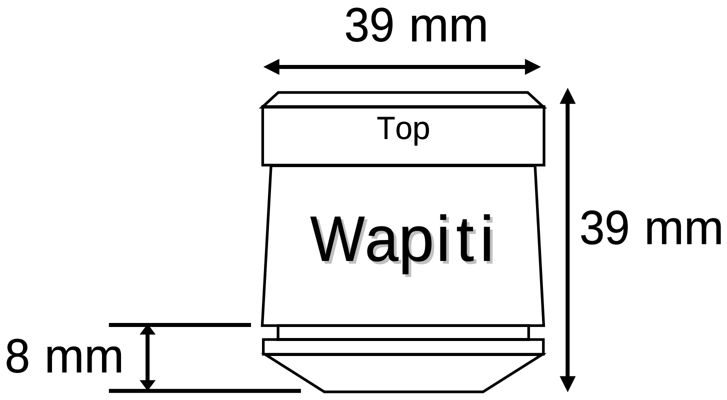
Thrust points for trajectography (flight prediction) simulation tools:

Time (s)	0	0.05	0.1	0.25	0.3	0.35	0.45	0.55	3.5	3.6
Thrust (N)	0	68	62	60	39	38	9	5	3	0

These data were collected during tests conducted in 1996 by the company LACROIX

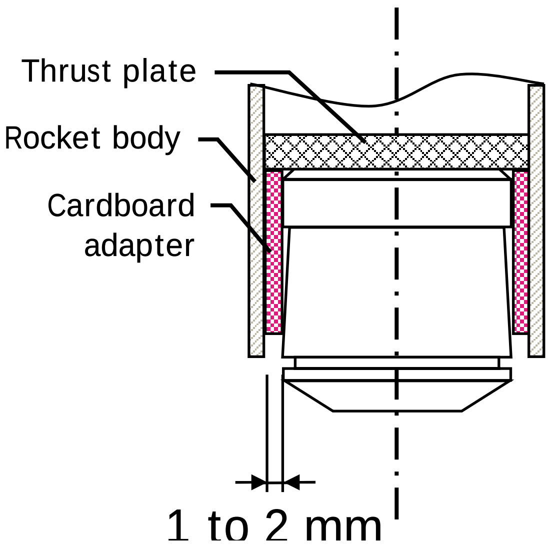
[2] Measured from the top of the motor – loaded or empty, Xcg of WAPITI is unchanged

Dimensions



Mechanical dimensions of WAPITI

Rocket interfaces



Assembly of WAPITI onto the rocket

CARIACOU

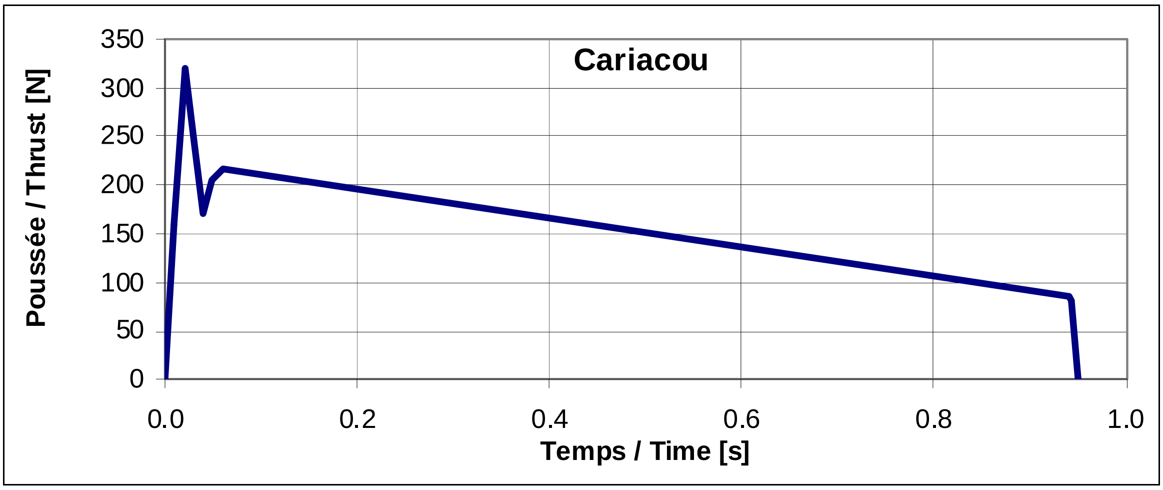
Presentation

CARIACOU is a motor for mini rockets since 2001; it is a type G motor based on rocket motors classification.

Specifications

	CARIACOU	Unit
Total impulse	145	N.s
Thrust duration	0.95	s
Maximum thrust	320	N
Average thrust	150	N
Total mass	220	g
Net mass	150	g
Centre of gravity[4] (loaded)	50	mm
Centre of gravity[4] (empty)	55	mm

Thrust Curve



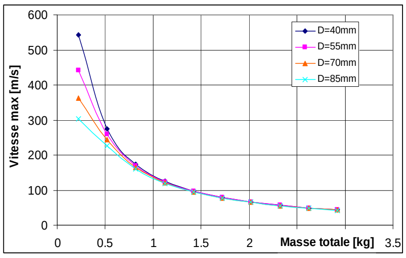
Thrust points for trajectography (flight prediction) simulation tools:

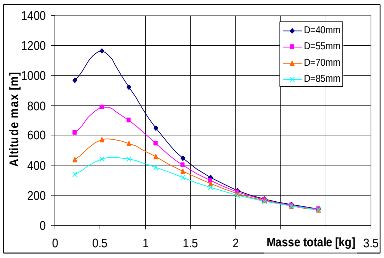
Time (s)	0	0.01	0.02	0.03	0.04	0.05	0.06	0.94	0.942	0.95
Thrust (N)	0	160	320	245	170	205	217	85	82	0

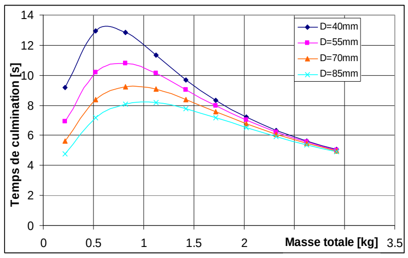
These data were collected during tests conducted in 2001 by the company *LACROIX*

[4] Measured from the top of the motor

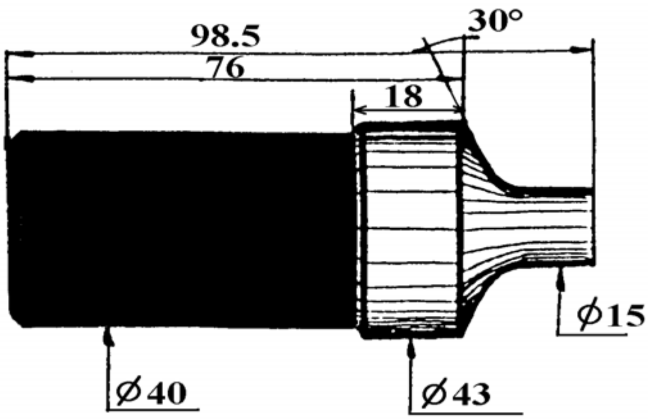
Performances

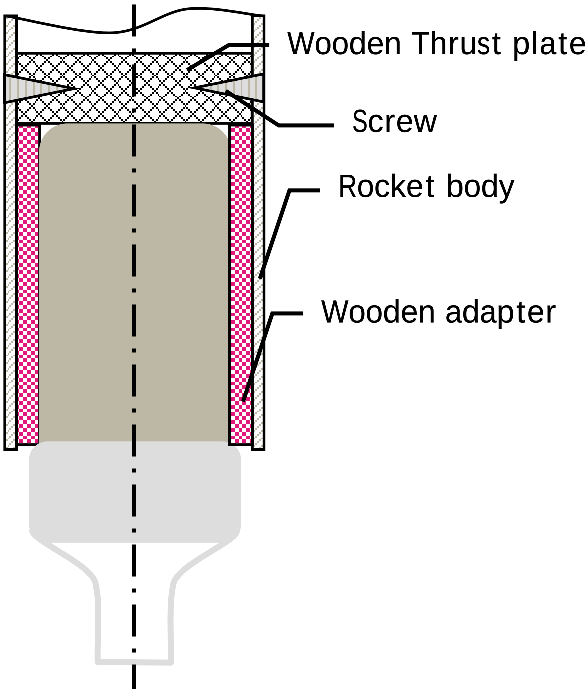






Dimensions and rocket interfaces





Note: motor case became very hot during flight.

PRO-X MOTORS

Since 2008, motors for experimental rockets presented by the CNES are extracted from **Pro-X** family of solid rocket motor manufactured by *Cesaroni Technology Incorporated* (CTI) in Canada, and retailed by *Rebel Rocketry* in Netherlands. Within the boundaries of European Union, the regulation CS 93/15.EEC, Module B, allows the use of these motors.

The CNES makes the following modifications:

- its set up process has been validated by CNES and Planète Sciences
- its transport, storage and destruction processes have been validated
- its ejection module is inhibited (Pro-54)

Indeed, the standard version of Pro-54 motors includes an ejection load (similar to the one inside micro-rockets motors) which is not used with the experimental rockets launched with the CNES and Planète Sciences.

Information can be browsed on their web site: www.pro38.com.

Rocket interfaces

Because of their shape (long and thin, non-plane top), Pro-X motors require several rings to maintain it in position.

These rings will either transfer the thrust to the rocket or center the motor or maintain the motor in its room. The allowed margin between the nominal diameter of the motor and the rim of the rings must be between 0.5mm and 1mm.

- The thrust transfer ring is bearing the force generated by the thrust of the motor; it must have a good mechanical resistance and must be strongly attached to the structure of the rocket.

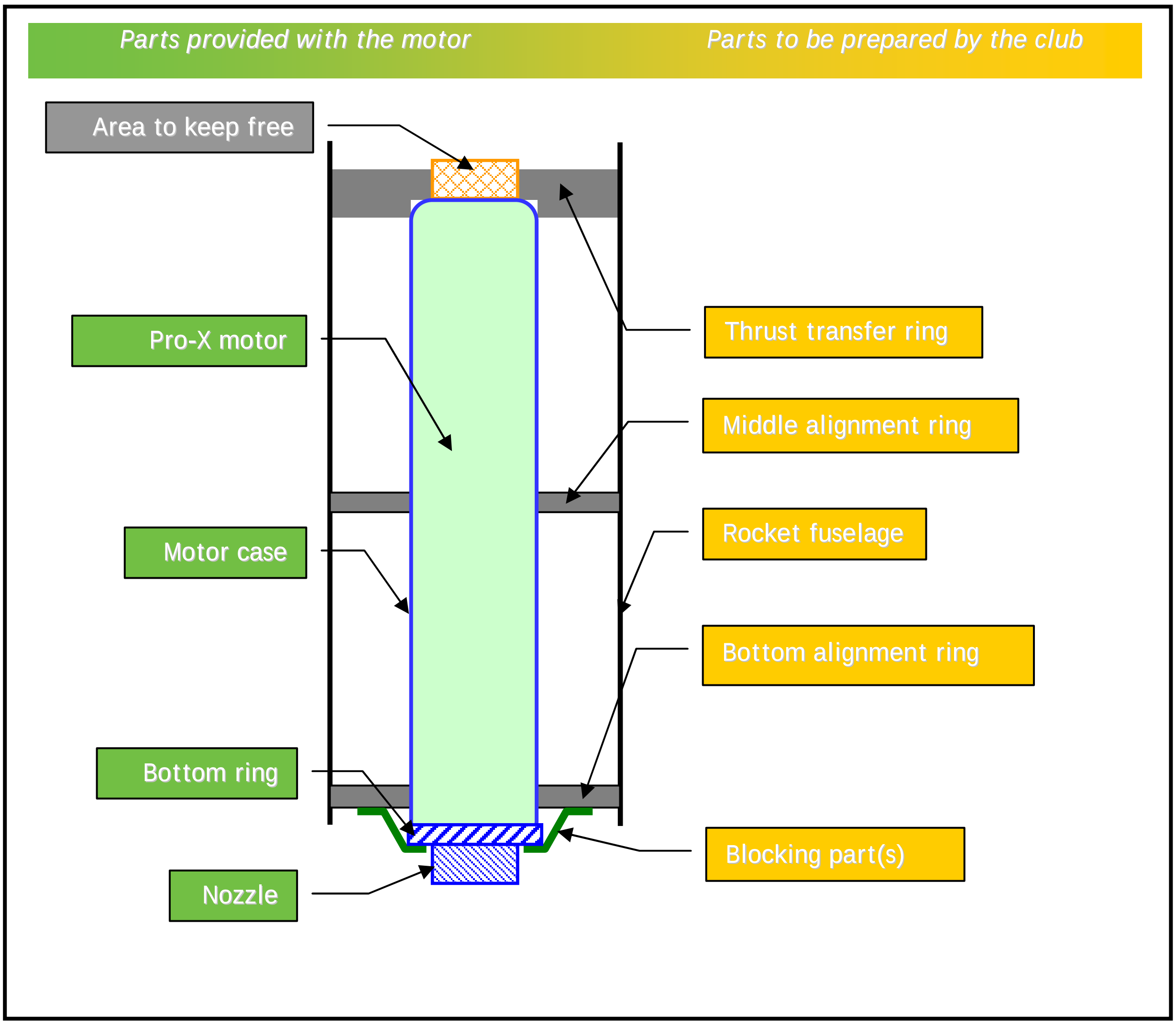
- The alignment ring(s).

- The blocking part(s), which is (are) attached to the thrust ring, is (are) intended to maintain the motor in its place while the rocket is in the launching pad and after the end of thrust. The set up of this (these) part(s) must be as simple as possible and require as few tools as possible (ideally none) because it will be performed by the pyrotechnician who is wearing gloves.

There are two ways to transfer thrust from Pro-X motors to the rocket, detailed in the following pages.

Top thrust transfer

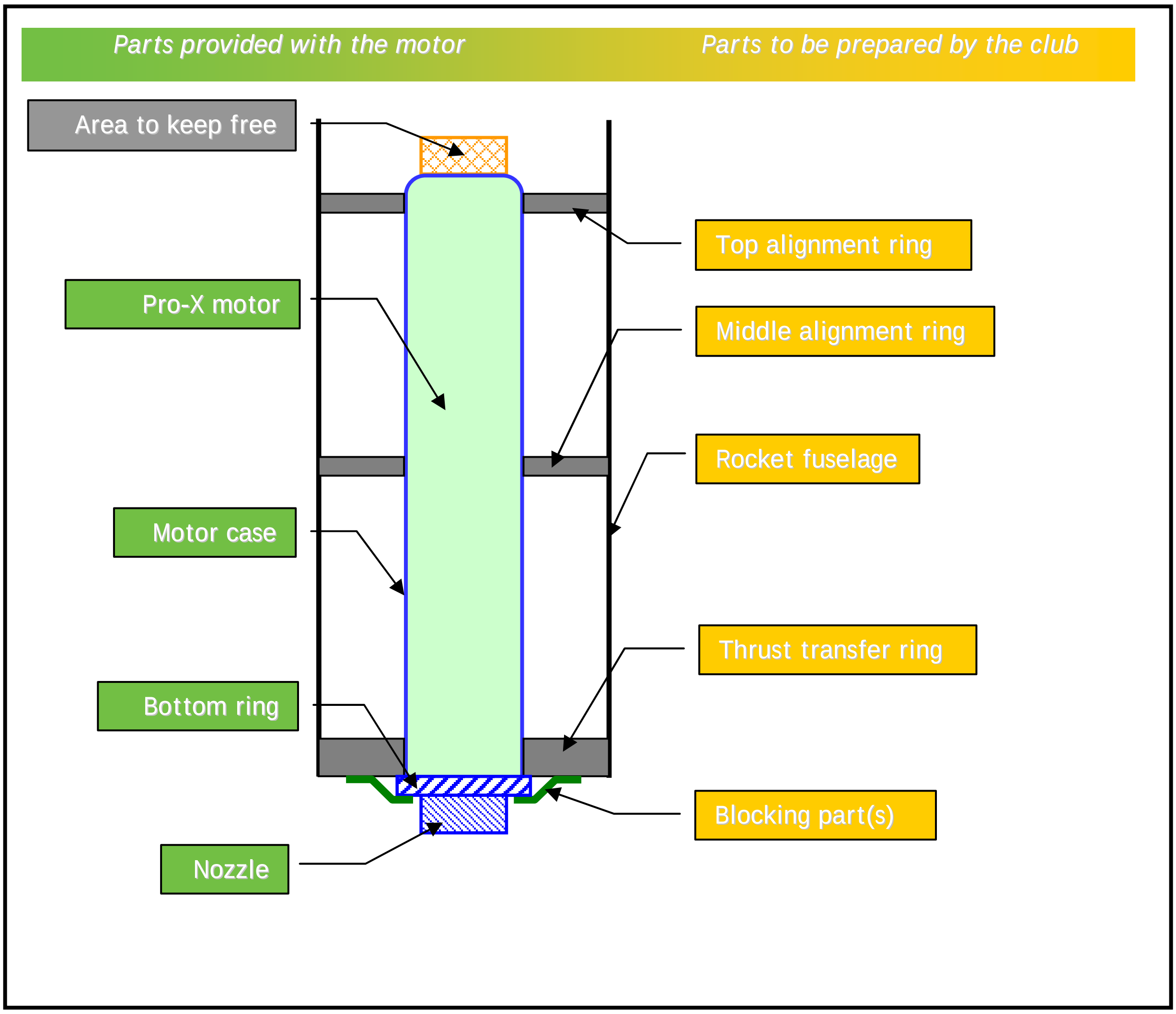
In this case, thrust is transferred from the top of the motor. This thrust transfer area is somewhat narrow therefore great care will be taken to the manufacturing of the thrust ring. This type of thrust transfer has been prooved by tests performed on the *Malychka* rocket series.



Bottom thrust transfer

In this case, thrust is transferred from the bottom ring of the motor to a Thrust transfer ring of the rocket. This thrust transfer area is somewhat narrow therefore great care will be taken to the manufacturing of the thrust ring. This ring also ensures the alignment of the bottom of the motor.

In 2007, mechanical tests conducted by ESO – the space club from the engineering school ESTACA - demonstrated that the thread of the retaining ring allows thrust transfer.



BARASINGA (PRO54-5G)

Presentation

Barasinga is the name given by CNES / Planète Sciences to the "Pro54-5G classic" from *Cesaroni Technology Incorporated* (CTI), without the ejection module.

This motor has been first used with the rocket « Malychka » by Planète Sciences, launched in United Kingdom on September 29th 2006.

A dedicated launching campaign has been organized in March 2007 in order to gain experience with its set up and to check flight performances.

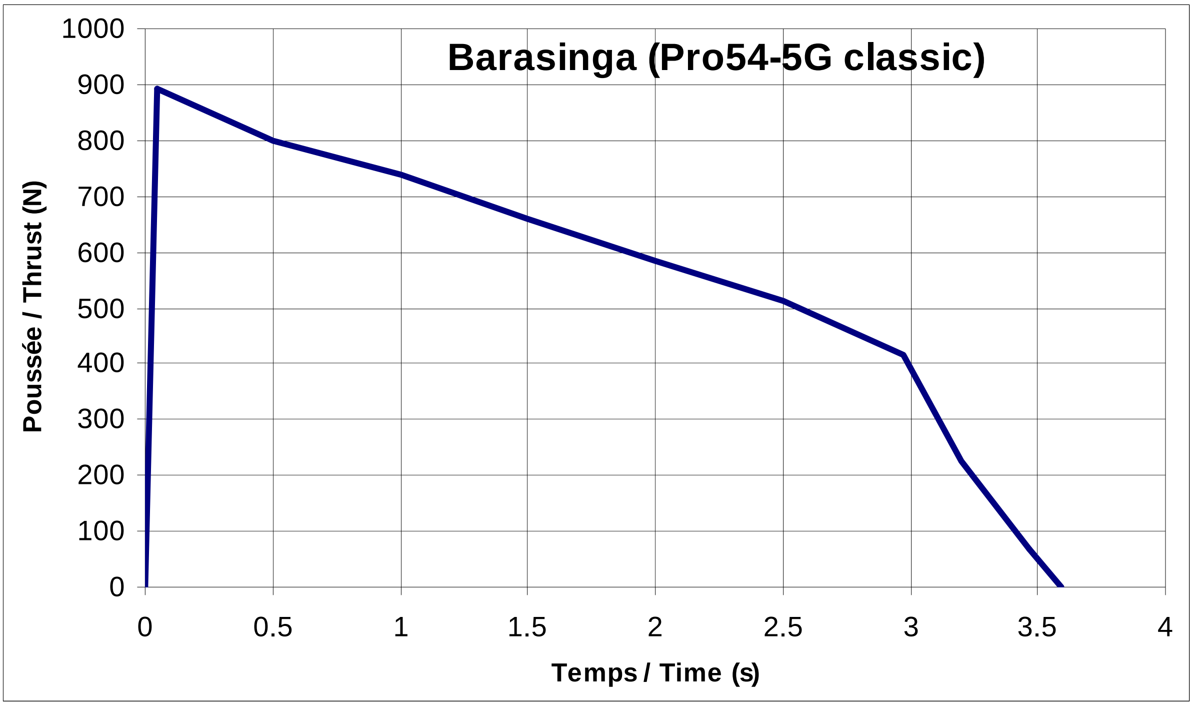
This motor was then set up during the launching campaign organized in La Courtine in July 2007. The rocket *Belenos* from the club Aero-Ipsa made a successful flight. CNES and Planète Sciences are then considering that Barasinga motor is fully qualified for use in Experimental rockets.

Specifications

Description	Value	Unit
total weight	1.685	kg
burnout weight[7]	0.652	kg
propellant weight	0.990	kg
center of gravity (loaded) [8]	250	mm
center of gravity (empty) [8]	240	mm
total length	488	mm
nominal diameter of metal case	54.0	mm
maximal diameter of metal case	54.5	mm
maximum thrust	893	N
average thrust	574	N
total impulse	2063	N.s
burn duration	3.59	s
specific impulse	212.5	s

[7] Part of thermal protection and nozzle are consummed.
[8] Measured from the top of the motor (cf. motor dimensions schematic).

Thrust curve

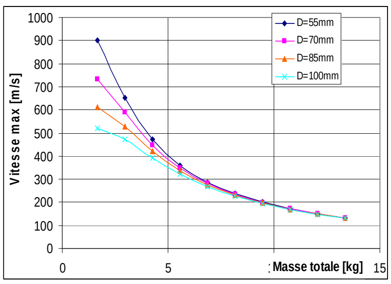


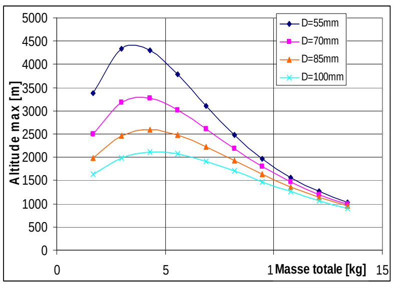
Thrust points for trajectography (flight prediction) simulation tools:

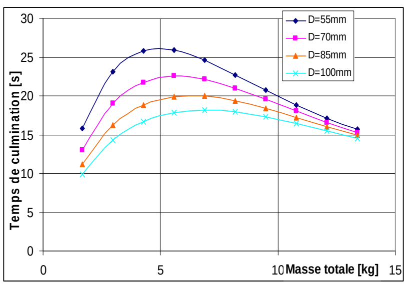
Time (s)	0	0.05	0.5	1	1.5	2	2.5	2.97	3.2	3.47	3.59
Thrust (N)	0	893	798	739	659	586	513	417	225	67	0

These data comes from the file www.pro38.com/rasp/proxx.eng (June 2006).

Performances

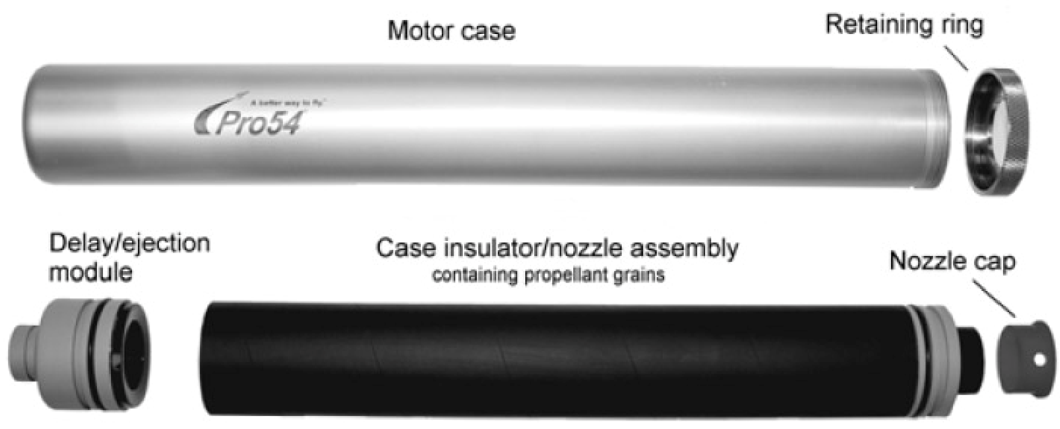


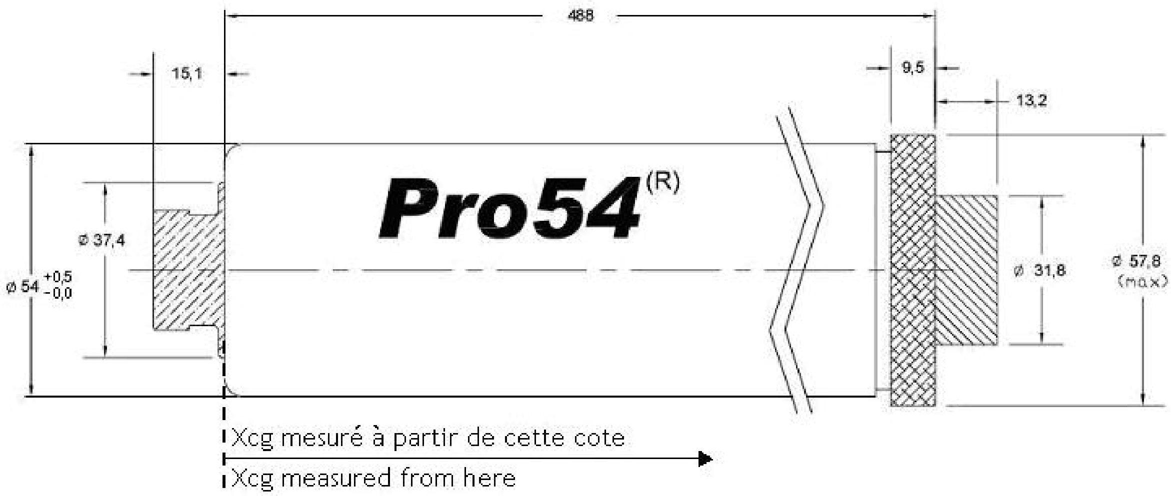




Dimensions

Remark: motors launched during the campaigns organized by CNES / Planète-Sciences can not use the delay/ejection module (disabled).





dimensions unit: millimetre

PRO75-3G

Presentation

The Pro75-3G motor is basically a “Pro75-3G classic” from *Cesaroni Technology Incorporated* (CTI).

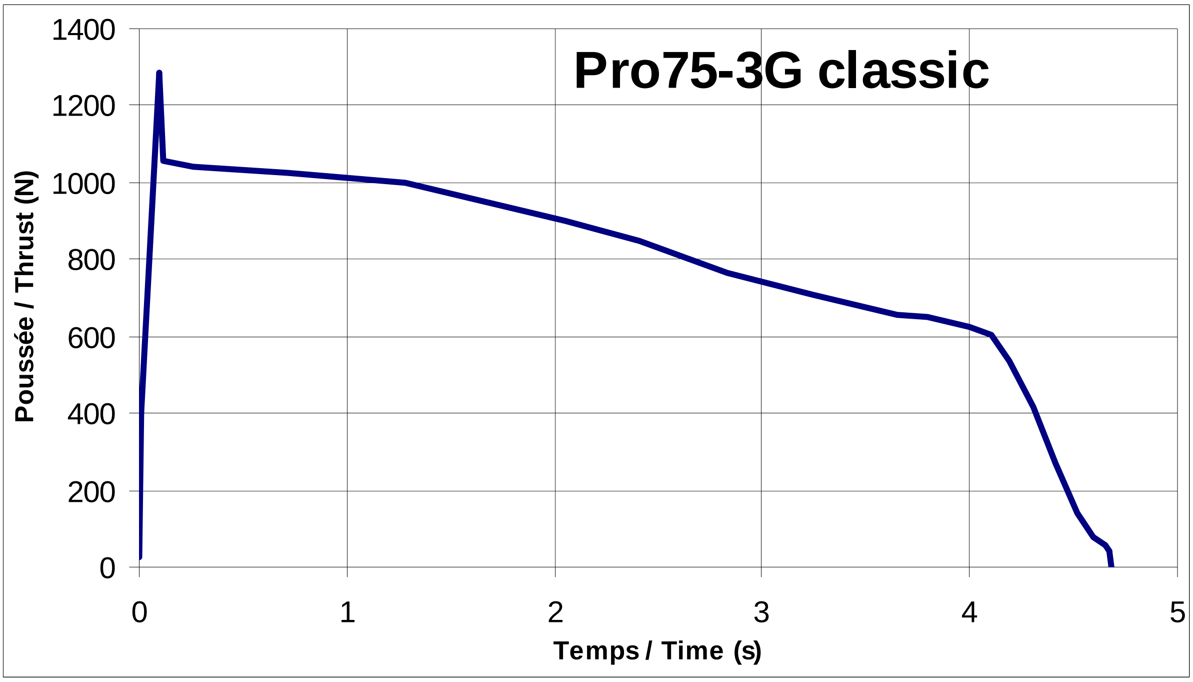
This motor is not yet qualified to be used by clubs. Ask info to Planète Sciences.

Specifications

Description	Value	Unit
total weight	3.511	kg
burnout weight	1.638	kg
propellant weight	1.795	kg
center of gravity (loaded) [10]	250 ?	mm
center of gravity (empty) [10]	240 ?	mm
total length	486	mm
nominal diameter of metal case	75.3	mm
maximal diameter of metal case	75.8	mm
maximum thrust	1286	N
average thrust	804	N
total impulse	3757	N.s
burn duration	4.67	s
specific impulse	213.5	s

[10] Measured from the top of the motor (cf. motor dimensions schematic).

Thrust curve

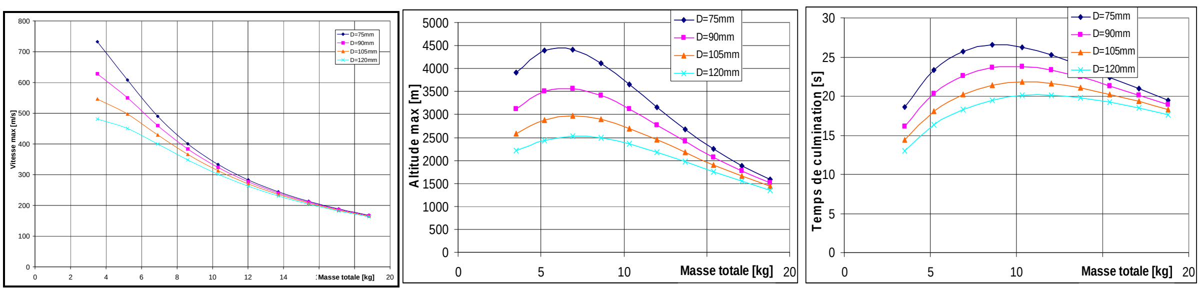


Thrust points for trajectography (flight prediction) simulation tools:

Time (s)	0	0	0.01	0.1	0.12	0.26	0.71	1.28	2.05	2.41	2.83	3.25
Thrust (N)	0	27	402	1286	1057	1042	1027	998	901	850	764	707
Time (s)	3.65	3.8	4.00	4.1	4.19	4.31	4.41	4.52	4.6	4.65	4.67	4.68
Thrust (N)	655	652	624	601	536	416	270	140	77	55	40	0

These data comes from the file www.pro38.com/rasp/proxx.eng (June 2006).

Performances



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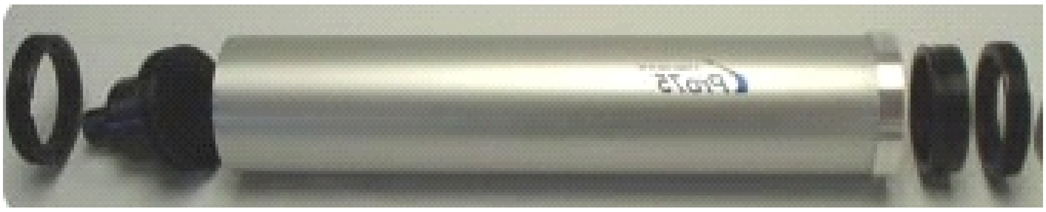
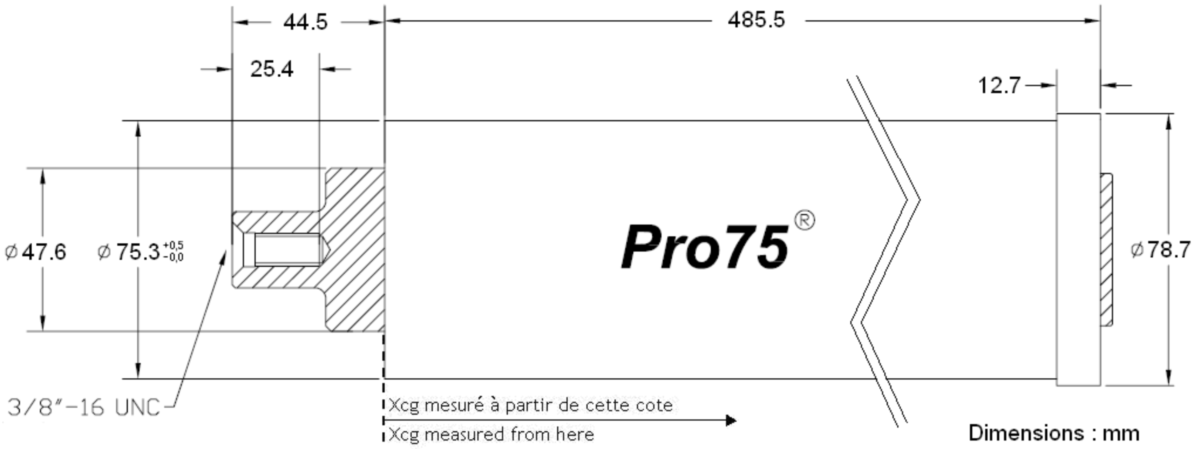



44.5
485.5
25.4
12.7
⌀47.6
⌀75.3 +0.5 -0.0
Pro75®
⌀78.7
3/8"-16 UNC
Xcg mesuré à partir de cette cote
Xcg measured from here
Dimensions : mm

HISTORY

CNES policy for amateur rockets motors has started in 1973. Its target was to provide young amateurs with a complete range of motors. The objectives of this policy have been driven by the experienced gained on previous generation of motors (**Cabri**, **Atef**, **Elan**, **Faon**), that is to say:

- A coherent motor range allowing a large choice for performances
- Safety during operations
- Low cost
- Wide availability

This conducted the CNES to manufacture motors purposely designed for clubs: **Chamois** (1974-2008), **Isard** (1982-2008) and **Caribou** (1982-1998). The technical choices made at that time were:

- A reloadable motor, simple from a mechanical point of view,
- SD type powder with low combustion temperature
- An extruded powder load, manufactured from existing professional tools: *Targon*, *Souges* and *Ruchard* powder block
- An initialization system with an ignition cane, in order to allow cocking the motor at the last minute before launch.

Apparition of small experimental rocket and minirocket activities (1983) incited the CNES to use commercial motors (low cost and large availability). **Bambi** (1979-1985) was the motor of a rocket which aim was to prevent hail from spoiling the crops produced by company *Ruggieri*, **Dick-Dick** (1985-1991) was the motor of a distress rocket, and **Wapiti** (1998-…) is a based on a flare from society *Lacroix*.

Koudou (1987-2003) and **Cariacou** (2001-…) are produced by the compay *Lacroix* after an open tender from CNES to industrials.

In 2006, before Chamois went out of stocks, researches have been carried out to identify a successor among the existing motors. The company *Cesaroni* provides a wide choice of motors dedicated to rocket amateurs, and its Pro54-5G has been selected for our launch campaigns under the name **Barasinga**.

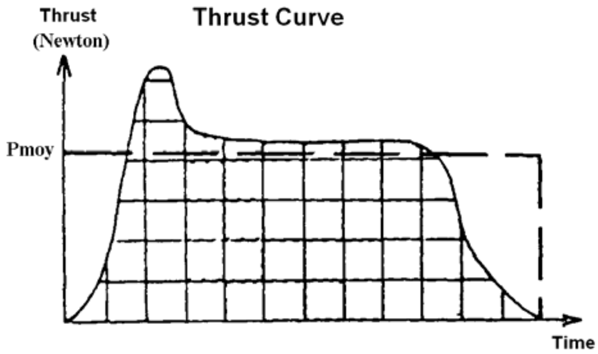
This range of motors is not frozen. Each year, Planète Sciences, CNES and motor-manufacturers are working on improving the motors' range. Clubs willing to contribute in this effort are invited to contact Planète Sciences.

PYROTECHNICIAN VOCABULARY

Common definitions

SPECIFIC IMPULSE (ISP, s) is a parameter which determines the efficiency of a motor. It is the impulse given by 1kg of propellant during 1s. ISP=Thrust/(g x ṁ) with g as the constant of gravity and ṁ as the Mass Flow.

THRUST is the force exerted by the motor on the rocket during the propelled phase.



TOTAL IMPULSE (It, N.s) is the integer of the thrust versus time function. Practically, it is calculated by summing [thrust x time interval] where thrust can be considered constant (see picture above). From a geometric point of view, It is the surface below the thrust plot.

AVERAGE THRUST (Pmoy, N) is the constant value thrust during burn duration so that the product "average thrust" x "burn duration" is equal to total impulse: *Pmoy =It/t*

People

A PYROTECHNIST is a person with the required professional skills to use or manufacture explosive compounds or objects.

A PYROTECHNICIAN is a specialist who designs, manufactures or uses explosive compounds or the pyrotechnic system they form.

Ignition

AN INITITIATOR is a generic name for a part that activates a pyrotechnic reaction (detonation, explosion or combustion).
Example: hot wire initiator type SA2001 for mini-rockets or SA2351 for experimental rockets, manufactured by the *Davey Bickford* Company.

AN IGNITER is a special initiator which produces a flame and as a consequence that is ready to start combustion.

Propellants

A PROPELLANT is a product composed of one or several ergol, either separated or gathered, that form a mix or a compound capable of providing the propulsion energy of a rocket motor.
Example: catergol, diergol (or biergol), hypergol, monergol, triergol.

A COMPOSITE PROPELLANT is a solid propellant composed of a tight mix of fuel (the plastic binder sometimes produces energy) and combustive material, to which is generally added a pulverulent metal which is acting as a reducing agent supplement.
Example: load of the motors Cariacou, Pro54 and Pro75

A HOMOGENEOUS PROPELLANT is a solid propellant for which the main compounds form a single phase which contains the oxidizer and reducing elements. Example: double base propellant mainly composed of nitrocellulose and nitric ester (usually nitroglycerin).

A PROPELLANT SD is a French name of a homogenous propellant manufactured without solvent; shaping is performed through hot and vacuum extrusion of a thermoplastic mix of nitrocellulose and nitroglycerin (or other nitrate oil). Jellification is performed through laminating.
Example: *Souges* and *Targon* blocks for Isard and Chamois motors

Protections

A THERMAL PROTECTION indicates all the materials used, usually on a motor's structure walls, to protect it against internal or external heat increase.

AN INHIBITOR is a coat or a material that slows or prevents unwanted chemical reactions to happen, in order to master its combustion mode.

MOTORS CLASSIFICATION

The practice of activities as well as security conditions are ruled out by the energy available in the motor. A classification based on Total Impulse, which is the product of the average thrust by the effective duration of thrust, summarizes the motor types. One usually designate a motor with the letter of its type and the value of its average thrust (in Newton). The types are defined in geometric progression with factor 2:

Type	Impulsion (N.s)	Category	Example
A	0 to 2.5	MicroRocket	A8-3
B	2.5 to 5		B4-4
C	5 to 10		C6-3
D	10 to 20	MiniRocket	
E	20 to 40		Wapiti (E10)
F	40 to 80		
G	80 to 160		Cariacou (G150)
H	160 to 320	Experimental rocket Sounding rocket	
I	320 to 640		
J	640 to 1280		Isard (J600)
K	1280 to 2560		Pro54-5G (K570)
L	2560 to 5120		Pro75-3G (L800)
M	5120 to 10240		Caribou (M3780)
N	10240 to 20480		
O	20480 to 40960		
P	40960 to 81920	Satellite launcher	
...	...		

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